REDUCTION OF TEMPERING TIME IN MILLING BY MINIMAL FISSURING OF WHEAT

by

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Individual Parts of this dissertation were prepared as required by the journals to which they will be submitted and are, therefore, not uniform in style.

SECTION A: A STUDY DOCUMENTING REDUCTION OF TEMPERING BY FISSURING AND ITS EFFECT ON MILLING.

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INTRODUCTION

Milling is the controlled disintegration of the whole wheat kernel to separate the endosperm, bran and germ.There are various steps involved in milling before the wheat could be ground into flour i.e. cleaning and conditioning.
Cleaning is the 1st step i.e. the wheat from the elevator contains a lot of dust and foreign material which could cause fires,damage the machinery and reduce flour quality. So they are subjected to cleaning using machines like aspirators, millerators scalpers and magnets.

After the wheat has been cleaned it is subjected to conditioning which is one of the most important factors involved in milling. If a mill is to be well balanced and skillfully operated , the miller should ensure a uniform flow of conditioned wheat to the grinding system.

Wheat conditioning can be defined as the treatment of wheat by a combination of moisture time and in some cases heat. This is one of the most complex aspects of milling. The purpose of conditioning is to prepare the particular wheat being milled to the optimum condition for milling,i.e. to toughen the bran and mellow the endosperm, so that it fractures more easily and will improve the milling operation.

There are different kinds of conditioning and this could be broadly classified into four categories.

1> Cold Conditioning:This is commonly referred to as

tempering.This is the addition of water to wheat and holding it for a specified period of time without addition of heat.

2> Hot Conditioning: This refers to the use of heat to bring the temperature of the wheat or the water or both to a temperature above $115^{0}F$ and less than $125^{0}F$. Since at temperatures above $125^{0}F$ proteins are denatured and gluten loses its strength.

3> Warm Conditioning:This refers to the use of heat to bring the temperature of the wheat or water or both to a maximum temperature of $46^{0}C$ or $115^{0}F$. Heat acts in the acceleration or penetration of water into the kernel.It sets up a moisture gradient with more in the bran and less in the endosperm.

4> Steam Conditioning:This is the application of direct low pressure live steam to the wheat kernels with the kernels acting as condensers.Temperatures of $115^{0}F$ to $120^{0}F$ are achieved. As temperature increases the rate of water penetration also increases.

A holding period prior to milling in a weather restricted tempered bin allows the water penetration into the wheat kernel.This time varies depending upon the type of wheat and type of conditioning.

Objectives

The main objectives of this research are :

1> To determine the roll gap for the pre-break for minimal fissuring.

2> To determine the optimum conditioning time for fissured Arkan Hard Red Winter Wheat.

3> To evaluate the milling properties of fissured Arkan Wheat in terms of yield, color, and ash in comparison to non fissured Arkan Hard Red Winter Wheat.

REVIEW OF LITERATURE

The entry of water into the wheat kernel depends on several factors like kernel structure,time and temperature,kernel size,internal fissures,scouring,and texture.All these factors have a role to play in the conditioning of wheat.

Kernel size: Moisture movement in wheat is primarily dependent on the kernel structure.Moisture may be added to wheat by immersion,tempering,or wetting the grain or by exposure to air of high humidity.Moisture movement occurs within the wheat kernel by diffusion with some degree of capillary action on or near the outside surface of the grain towards the crease.(1)(2).

It was once thought that the major portion of the wheat kernel was surrounded by an impermeable membrane so that moisture was introduced by way of the beard and placenta or by the small aperture the micropyle.Pence and Swanson (3) found that when wheat was immersed it picked up water rapidly at first (7-10%) within the first 10 mins at room temperature then the rate of absorption decreased with time.This was due to to the permeability of the bran coat.Thus the bran coat does have a great affinity for water than the endosperm of the wheat(3).

Bradbury,Cull and Macmasters outlined the path of moisture entry into the wheat kernel.The attachment area at the base of the kernel is the the only region that permits

immediate and rapid entrance of water.This is the only portion not covered by the cuticle.The parenchyma tissue located in the attachment area contains numerous intercellular spaces.Rapid movement of water takes place upward from this spongy tissue,through the pericarp and into the area of thin walled cells.This maze of intercellular spaces,among them intermediate tube and cross cells along the dorsal surface of the kernel,forms another pathway for rapid movement of water.The spongy parenchyma on the crease side connects with the pericarp tissue in the "V" of the crease and with relatively large air spaces which formed during maturation.

Hinton.J.J.C.(5) after removing successive layers of the outer surface,measured the rate at which water was absorbed from a capillary tube in contact with wheat kernels,postulated that the testa is the most important barrier to water penetration.

Moss(6) was able to show that the major barriers to the diffusion of water into the endosperm are primarily the outer cuticle and the testa as these contain waxy hyrophobic cells which effect the rate of water penetration .

Milner and Shellenberger (7) noted that after moistening and drying the wheat kernel several times the endosperm was fissured and cracked.The treated kernels absorbed water faster than untreated ones.This rapid moisture pickup was attributed to the cracks in the

endosperm.

TIME AND TEMPERATURE:Pence and Swanson(3) observed two stages of moisture absorption by an immersed kernel of wheat.First there is a rapid intake of moisture followed by a gradual decrease in intake as the length of time increases.A small change in immersion time has greater effect with shorter immersion time.

Jones(8) reported that water penetration into the wheat kenel could be classified into 3 periods:

a>A rapid intial intake due to bran hygroscopity

b>A period of rapid decrease in moisture pickup.

c>A slow and steady period of water absorption.

The relationship between moisture content and time in this period is almost linear.

(3)Temperature has no apperciable effect during the initial rapid intake of moisture.After the grain has been soaked 2 mins,an increase in temperature results in increased rate of absorption.

Jones and Campbell(9) reported that a rise of 12^{0}C between 20 ^{0}C and 43.5^{0}C,causes a three fold increase in the speed of the moisture movement to the cheek center.The increase in speed of moisture movement to the cheek center ceases abruptly above 43.3^{0} C.From 49^{0}C to 60^{0}C there is no increase in the speed of the moisture movement.

Fraser et al(10) and Pence et al(3) reported that complete saturation of a wheat kernel was reached from 2-3

hours of temper at room temperature.It was noted by (11) that when an increase of 5% was added to vitreous Manitoba wheat the center of the cheek received about 1/2 its final moisture increment in about 5 hrs.After 24 hrs it had aproximately 85% of its final moisture increment.The moisture movement in this part was not complete until after 60 hrs.(11) also developed a method for determining small changes in moisture content of small endosperm particles by utilizing the change in density.Complete saturation of the kernel has been reported in the literature as taking from 2-3 hrs(3) at room temperature.

Zwingleberg(12) stated that following wheat dampening a moisture ring enveloped the berry.In damped soft wheat ,moisture penetrated the peripheral endosperm layers more rapidly than is so with hard wheat.Soft wheats are completely saturated in 10-12 hours compared to 20-24hrs or more with hard wheats.He also concluded from the moisture ring enveloping the berry that after a short time of 1-3 hours,all layers high in ash content would have been dampened by water and the grain will be suitable for grinding.Finally he carried out milling tests and concluded that the most favourable ash content was obtained after a period of 24 hours of temper time.For hard wheats the moisture ring failed to reach all the layers high in ash within the first 1-3 hours.

Kernel Texture: Fraser and Haley(10) reported that the

wheat type,endosperm character and wheat grade influence the rate of water absorption by wheat kernels.Soft wheats absorb moisture more rapidly than hard wheats.Winter wheat varieties exhibit more rapid absorption than spring wheat varieties.Starchy or mealy endosperm will absorb moisture more rapidly than vitreous endosperm.And low protein content in wheat tends to absorb moisture more rapidly than high protein content wheats.

Herd(13) reported that soft wheats absorbed moisture more rapidly than did hard wheats.

Wilson(14) in his study of compositional variations in the bran layer of wheat and their relation to milling,concluded that besides the thickness and physical nature of the bran which slows water penetration the hydrophilic pentosans present in the bran layers tend to bind water and prevent further movement.The movement of water from the sub-aleurone layers of the endosperm into the center of the grain is probably not influenced by the pentosans.He also stated that the starchy endosperm cell walls contain similar arabinoxylans to those found in bran and these may influence the rate of water movement into the central endosperm.

Zwingleberg(12) attributed the difference in moisture absorption and tempering between hard and soft wheat kernels to the chemical composition of the sub-aleurone layer.He stated that in hard wheat kernels in the sub-aleurone there are cells which are of compact structure and high in albumen

content.In soft wheat kernels the same area contains fewer sub aleurone cells which are rich in starchy material.Water therefore is able to penetrate this starchy area faster,and given the same tempering time,the albumen rich area in the hard wheats is insufficiently penetrated by water.Hard wheats therefore require not only more moisture than soft ones but also a more extended tempering time.

Kernel size:(10)At an equal weight smaller kernels of grain absorbed moisture at a faster rate than larger ones.This difference was due to the larger absorbing surface area of the smaller kernels of grain in relation to their weight.

Internal fissures:Fisher and Hines(15),Shellenberger and Milner(7) found that wheat which had been moistened and dried several times had fissures and cracks in the endosperm.Wheat treated in this manner absorbed water at a faster pace than untreated or unfissured wheat.

Scouring:Campbell(16) and Zwingleberg (12) showed that scouring resulted in an increase in rate of water absorption when immersed for a minute in water. Campbell (16) reported that the rate of moisture penetration into the endosperm is increased only in the peripheral dorsal region of the the endosperm.The beard end is responsible for the greater part of the increased rate of moisture penetration.

Conditioning split wheat.

Hodler(17) investigated tempering split wheat by splitting 16 samples of hard wheat on smooth rolls operating at 1.5:1 differential.Each sample consisted of 1500 gms of wheat.Two sets of trials were run with 8 samples of split wheat and 8 samples of whole wheat in each set of trials.One set was tempered to 16% moisture and the other set was tempered to 18% moisture.The samples were then milled after 3/4,1 1/2,2,4,8,18,30,48 hours of tempering time respectively.

Hodler(17) concluded that splitting hard vitreous wheats before tempering may be expected to speed up the tempering as indicated by studying the % ash and the dough mixer curves of the flour. In addition the percent ash of the straight grade flour was lower in all cases but two. Dough mixer curves of flours indicated that splitting the wheat before tempering speeded up tempering in the first few hours. Examinations of both dry and wet Pekar tests did not reveal any significant color variations.

A micro-milling procedure for milling 100 gms samples of wheat was developed by Finney and Yamazaki(19) which consisted of two to three pre-breaks through the rolls of a Tag-Heppenstall ,moisture meter and one break and two reductions on a specially designed Hobart grinder.The flour ash and protein contents were comparable to those of straight grade flour from conventional Allis-Chalmers and

Buhler experimental mills.This micro-milling was sucessfully applied 100 gms of plant breeders early generation progenies through the 1961 crop(20).Finney and Bolte (18) developed a micro-milling method whereby a wheat was given a 2% pre-temper for 15 mins,a pre-break and a temper to the desired moisture level for 15 mins,a second pre -break and then micromilled,the total time was about 40 mins.The straight grade flour yield,protein and ash values were comparable to those of flour milled from wheat tempered for 18-24 hours.The 2% pre-temper toughened the bran so that when the wheat was given the 1st pre-break through the Tag-Heppenstall rolls,the bran remained relatively intact and held together the shattered and fissured endosperm.Consequently the endosperm acted like a sponge and quickly and relatively uniformly absorbed the temper water in about 15 minutes.

(21)Finney and Andrews conducted a study as to wether soft wheats could be given a 30 minute temper and produce micro-milled flours with yield,moisture,ash,damaged starch,and cookie quality comparable to those tempered to 18-24 hours.Their secondary purpose was to determine wether 1.5 or 10 kg quantities of soft wheat tempered for 30 minutes and experimentally milled an an Allis-Chalmers or Miag-Multomat would yield straight grade flours comparable to those tempered for 18-24 hours.

The wheat was conditioned for 30 minutes,and it

involved a 2% pre-temper for 15 minutes,a pre-break,a final temper for 15 minutes and an optional second pre-break.This method was successful for milling 200 gms of soft red winter wheat on two Quadrumat Juniors,1.5 kg on an Allis-Chalmers mill,or 10 kg on a Miag Multomat Mill.Flour moisture,yield, ash,damaged starch,and cookie quality were comparable whether tempered 18-24 hrs or tempered a total of 30 minutes using the pre-break method.

Pomeranz etal (22) studied the effect of variations in tempering on Micro-Milling of Hard winter wheat.Three variations in tempering were used to micro-mill 100 gm samples of 12 hard red winter varieties that varied widely in weight per bushel,kernel weight,protein and ash contents,and kernel hardness.In all three variations the wheat was tempered to 15% moisture and was passed through two pre-break treatments.In variation A the 1st pre-break was made 1 & 1\4 hour, after water addition,and the wheat was rested for 1\4 hour before the second pre-break.In the other two variations(B & C) the two pre-break treatments were made 2 & 24 hours after water addition respectively, with practically no intermediate rest.The three variations in tempering were also applied to 3 hard red winter wheats of different hardness characterstics, each from four locations.The yields of flours milled by the variations in tempering were about 69% and flour ash was about 0.35%.Flour obtained by micro-milling of the three variations in

tempering were comparable in protein content and bread making characterstics.They concluded that the pre-break treatments make it possible within 2 hours to produce flours for determination of gross composition and for evaluation of milling and bread making characterstics.

(23)Posner stated that fissuring of wheat kernels before water addition allows the moisture level of commercial wheat to increase from 8.5% to 16.6% in 12 hours of tempering time.Using Yecora Rojo wheat, flour yield,ash level and results from tests performed on flours did not show significant differences when comparing the short tempering to tempering methods practised in commercial flour mills.Blending whole or fissured Yecora Rojo with hard red winter after tempering did not result in significant differences either.His conclusions were that minimal fissuring of Yecora Rojo wheat kernels before tempering shortened water penetration time into the kernels. He stated that the method of fissuring the wheat kernel before tempering can hasten water penetration without a detrimental effect on the millability of the wheat and the resultant flour.

MATERIALS AND METHODS.

The wheat used in this experiment was the locally grown Kansas hard red winter Arkan wheat of the 1985 crop. Cleaned wheat was placed in drums and it had an initial moisture content of 12.5% and a test-weight of 62.8lbs/bu.

Conditioning : In this investigation cold conditioning was carried out as stated by Eustace and Farrell(25) on 1000 gm samples of wheat.The control consisted of 30 , 1000 gm samples of whole wheat kernels tempered to 16% moisture content and held in sealed plastic bags for 24 hours before milling.

The fissuring of wheat kernels was carried out as stated by Posner(23).200 wheat kernels were picked out at random and for each kernel two measurements were taken, one across the cheeks and the other across the crease.These two measurements were carried out using a micro-meter and were then averaged.Based on the experimental observations with this kind of wheat the gap between the pre-break rolls was set to 90% of the average kernel width which was 2.58 mm in this case.Prior to fissuring the wheat was pre-tempered to 0.5% moisture content for five minutes in order to ensure that the bran would stay intact during fissuring.

The wheats were then fissured using a pair of smooth 9x6 Ross experimental rolls operating at a 1:1 differential.Throughout the entire experiment the roll-gap

and the feed to the pre-break were kept constant. Effort was exerted not to crack the kernels completely but just enough to fissure their structure. The flow sheet of the process used for the control and the experimental sample is shown in Figure 1. In all 128 samples were used in the experiment out of which 81 samples were fissured. After fissuring, 27, 1000 gm samples were tempered to 15% moisture content and their lying times varied from 1 to 9 hours.The same procedure was carried out similar sample sizes but were tempered to 15.5% moisture content and 16% moisture content respectively with lying times varying from 1 to 9 hrs. The moisture levels for all the samples were detemined using a Dicky john Motomco Grain Moisture tester , Model 919.

All the samples were tempered using a laboratory type tempering system which consisted of a small revolving drum and graduated cylinder, for metering the water.

The final moisture content of the control sample was 16% and the for that of the experimental samples were 15.0, 15.5, and 16.0 % respectively. The water that was to be added to the wheat was calculated by the following formula.

$$((100-M1) / (100-M2) * W1) = W1 + X$$

where M1= % moisture in the untempered sample.

M2= % moisture in the tempered wheat sample.

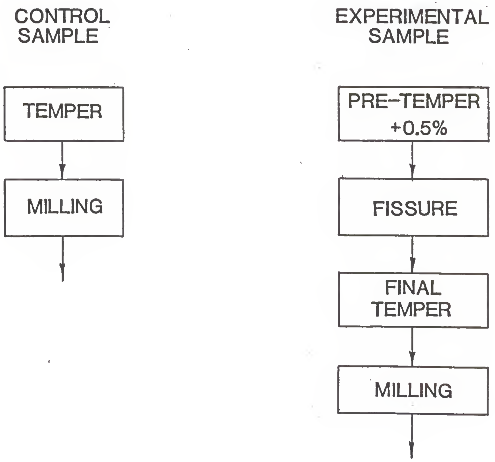
W1= weight of untempered wheat sample.

X = weight of water to be added.

The wheat samples were mixed with water for 15 minutes after

FIGURE 1

FLOW SHEET OF THE PROCESS



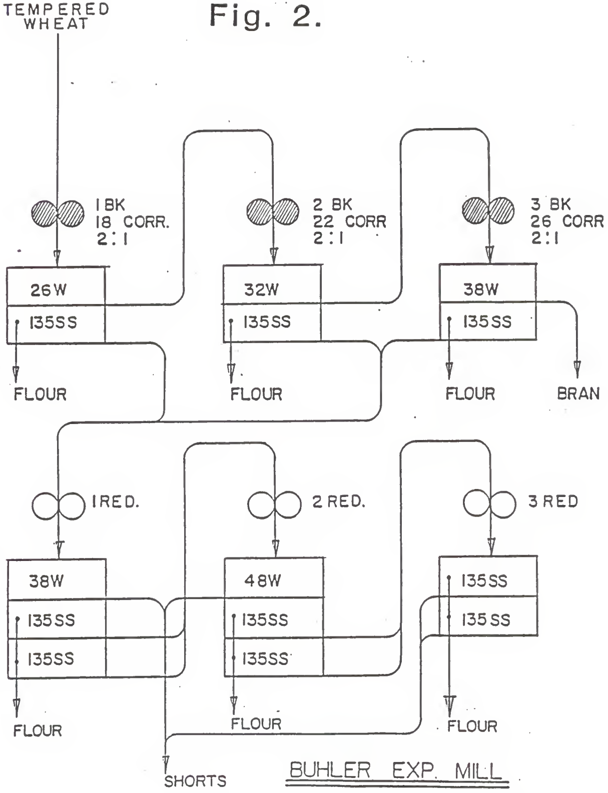
which they were placed in sealed plastic bags.

The experimental milling was carried out on a Buhler Experimental Mill which consists of 3 breaks and 3 reduction passages and its flow sheet has been indicated in Figure 2 . All the rolls have their own sifter sections. Material to each roll is conveyed pneumatically.The total roll surface is 400mm and the total sifting surface is 0.851 meters. The milling was carried out as per the approved A A C C method 26-20.The feed rate was set to approximately 100 gms per minute.Once the initial adjustments were made the roll gaps for the break and reduction system were maintained constant throughout the experiment.Prior to the starting of the milling of the experimental samples a warm up sample would be run to adjust the mill to the sample being milled and also to flush out the previous sample.All the samples were run in a sequence and this was carried through out the entire experiment.The milling sequence was as follows:

Warm up sample followed by the Control Sample and then the fissured sample which was the experimental sample.

The control sample was whole wheat kernels tempered to 24 hrs and the fissured samples consisted of samples with three levels of moisture ie 15.0, 15.5, and 16.0% moisture content respectively and with lying times varying from one to nine hours. All the fissured samples were run in triplicates in order to minimize the experimental error.All the products obtained from milling were carefully weighed and collected

Fig. 2.



BUHLER EXP. MILL

in plastic bags.Samples of each of the six flours were then analysed for moisture and ash analysis by the approved AACC method 08-01 and 44-19 respectively(24).

The milling yield was calculated on wheat milled and the color of the straight grade flour was determined using the Agtron dry color meter. The filth contamination test was conducted by the Acid Hydrolysis method an approved AACC method 24- 81 (24). For the filth test there were three samples namely A, B, and C respectively. The samples were throughly cleaned and prepared in the following manner. Sample A the control sample was aspirated and tempererd to 16.0% moisture content for 24 hours and aspirated again before milling. Sample B was aspirated and tempered to 16.0% moisture content for 24 hours and then subjected to the pre-break treatment.The roll gap on the pre-break was adjusted to 0.068 inches on the basis of earlier work done in the department by S.Curran (26). The sample was then aspirated and finally milled. Sample C was the fissured sample which was aspirated , fissured and aspirated and then tempered to 16.0% moisture content for nine hours and was given a final aspiration before being milled. All samples were run in triplicates. The aspiration was carried out on a Kice table top aspirator. The air flow on the aspirator was adjusted to 113 cfm and the feed gate opening was set at 1.2 cms. The counter units was set to 168. This was found as optimum operational conditions for the table top aspirator for

cleaning wheat on the basis of earlier work done in the department by Posner and Flores (27).

RESULTS AND DISCUSSION

The data obtained from the experiment has been shown in tables I to III. Extraction rates were computed based on finished products and their values have been indicated as seen in table I. Each value indicated is the mean of three samples. Similarly ash was measured using the standard AACC method and their results have also been indicated in the table II. Color of straight grade flour was measured using the Agtron Dry color meter, and the fragment counts were determined using the Acid Hydrolysis Method. In all there were 28 treatments and in order to find out the differences among the treatments i.e. control and the combinations of moisture and temper time, a one way analysis of variance was carried out on the data of ash, extraction and color. It was found that no differences existed in the case of extraction but differences existed for ash and color as seen from the p values of the test i.e. the p value for extraction was 0.9465, for ash it was 0.0017, and for color it was 0.0017. So once the F tests indicated that differences existed among the treatments for ash and color, the next step was to carry out a multiple comparison to determine where the differences occur hence the Least Significant difference (LSD) test was employed and the results have been indicated in tables IV,V,& VI.In the case of ash it was found that significant differences existed between the control and the treatments at temper

time 8 hours for moisture level of 16% ,and at temper time 9 hours for moisture levels of 15% ,15.5% , and 16.0% respectively as seen from table VI. In the case of color there were differences between the control and the treatments at temper time of 9 hours for moisture level 16.0% repectively as seen from table V.

In order to see how the moisture content and temper time were related to ash, color, and extraction, surface response planes were fitted to the data obtained using the SAS Regression procedure. The following relationships were obtained from the regression analysis.(where t & M are time and moisture content respectively.)

1. Ash= -0.00393631 t + 0.027098M

   $R^2 = 0.9973$

2. Color= .4245 t + 4.034 M

   $R^2 = 0.9996$

3. Extraction= 0.311 t + 4.104 M

   $R^2 = 0.9993$

These set of equations hold good for the ranges of time and moisture content present in this paper. By substituting values of M and t that were obtained from the experiments we found that the optimum combination of moisture and time to get the best results i.e high extraction and color and low ash, a tempering time of 9 hrs and a moisture content of 16.0% was necessary. Figures 3 to 11 indicate the cumulative ash curves for 1 to 9 hours of temper time , Figures 12 to

Table : I Percent Total Flour Extraction

Temper Time in hrs	Control (24 hrs)	Fissured Samples 15.0% m.c	15.5% m.c.	16.0% m.c
1	65.6	63.9	64.8	65.0
2	65.5	64.1	64.3	64.6
3	64.5	63.9	64.9	63.8
4	65.0	62.3	64.6	65.0
5	70.4	66.3	65.9	64.8
6	64.9	66.3	66.5	66.8
7	65.5	65.2	64.8	65.2
8	69.9	65.9	65.1	65.5
9	64.9	65.0	66.9	69.9

m.c. denotes moisture content

Table : II Percent Cumulative Ash reported on 14% moisture basis

Temper Time in hrs	Control (24 hrs)	15.0% m.c.	Fissured Samples 15.5% m.c.	16.0% m.c
1	0.420	0.433	0.406	0.413
2	0.409	0.392	0.390	0.400
3	0.401	0.432	0.423	0.406
4	0.419	0.392	0.397	0.412
5	0.414	0.398	0.399	0.406
6	0.422	0.419	0.417	0.421
7	0.420	0.415	0.406	0.390
8	0.410	0.391	0.393	0.383
9	0.421	0.369	0.344	0.372

m.c. denotes moisture content

Table : III Color Of Straight Grade Flour (Agtron Units)

Temper Time in hrs	Control (24 hrs)	15.0% m.c.	Fissured Samples 15.5% m.c.	16.0% m.c
1	65	62	63	64
2	66	63	64	65
3	66	63	64	66
4	65	64	64	66
5	65	61	63	64
6	64	63	65	66
7	65	63	64	65
8	66	65	66	66
9	64	67	68	71

m.c. denotes moisture content

Table :IV LSD Breakdown for multiple comparison among treatments for percent Total Flour Extraction

Treatment	Mean	Treatment	Mean
T9C16.0	69.96(ab)	T9C15.0	65.01(ab)
T9C15.5	66.9(ab)	T3C15.5	64.96(ab)
T6C16.0	66.87(ab)	T1C15.5	64.82(ab)
T6C15.5	66.59(ab)	T7C15.5	64.81(ab)
T5C15.0	66.33(ab)	T5C16.0	64.80(ab)
T6C15.0	66.30(ab)	T4C15.5	64.62(ab)
Control	66.27(ab)	T2C16.0	64.61(ab)
T5C15.5	65.96(ab)	T2C15.5	64.37(ab)
T8C15.0	65.91(ab)	T2C15.0	64.14(ab)
T8C16.0	65.54(ab)	T3C15.0	63.98(ab)
T7C16.0	65.22(ab)	T1C15.0	63.90(ab)
T8C15.5	65.11(ab)	T3C16.0	63.87(ab)
T1C16.0	65.05(ab)	T7C15.0	63.36(ab)
T4C16.0	65.0(ab)	T4C15.0	62.37(ab)

LSD = 7.27
Note: means within a column with the same letter are not significantly different at 5% level

Table :V LSD Breakdown for multiple comparison among treatments for Color

Treatment	Mean	Treatment	Mean
T9C16.0	71.0(a)	T2C15.5	64(efg)
T9C15.5	68.0(b)	T4C15.0	64(efg)
T9C15.0	67.0(bc)	T3C15.5	64(efg)
T8C15.5	66(bcde)	T5C16.0	64(efg)
T6C16.0	66(bcde)	T4C15.5	64(efg)
T4C16.0	66(bcde)	T7C15.5	64(efg)
T8C15.5	66(bcde)	T6C15.0	63(fgh)
T3C16.0	66(bcde)	T5C15.5	63(fgh)
Control	65.2(bcdef)	T3C15.0	63(fgh)
T6C15.5	65(cdef)	T7C15.0	63(fgh)
T8C15.0	65(cdef)	T1C15.5	63(fgh)
T7C16.0	65(cdef)	T2C15.0	63(fgh)
T2C16.0	65(cdef)	T1C15.0	62(gh)
T1C16.0	64(efg)	T5C15.0	61.0(h)

LSD = 2.28
Note: means within a column with the same letter are not significantly different at 5% level

Table :VI LSD Breakdown for multiple comparison among treatments for Ash

Treatment	Mean	Treatment	Mean
T1C15.0	0.433(a)	T2C16.0	0.400(cdefg)
T3C15.0	0.432(a)	T5C15.5	0.399(cdefg)
T3C15.5	0.423(ab)	T5C15.0	0.398(defg)
T6C16.0	0.421(abc)	T4C15.5	0.397(defg)
T6C15.0	0.419(abcd)	T8C15.5	0.392(efgh)
T6C15.5	0.417(abcd)	T2C15.0	0.392(efgh)
T7C15.0	0.415(abcd)	T4C15.0	0.391(efgh)
Control	0.413(abcdef)	T8C15.0	0.391(efgh)
T4C16.0	0.413(abcdef)	T7C16.0	0.390(fghi)
T1C16.0	0.413(abcdef)	T2C15.5	0.390(fghi)
T7C15.5	0.406(bcdef)	T8C16.0	0.383(ghi)
T1C15.5	0.406(bcdef)	T9C16.0	0.372(hi)
T5C16.0	0.406(bcdef)	T9C15.0	0.368(i)
T3C16.0	0.406(bcdef)	T9C15.5	0.343(j)

LSD = 0.02263
Note: means within a column with the same letter are not significantly different at 5% level

FIG. 3

1 HR. FISSURED

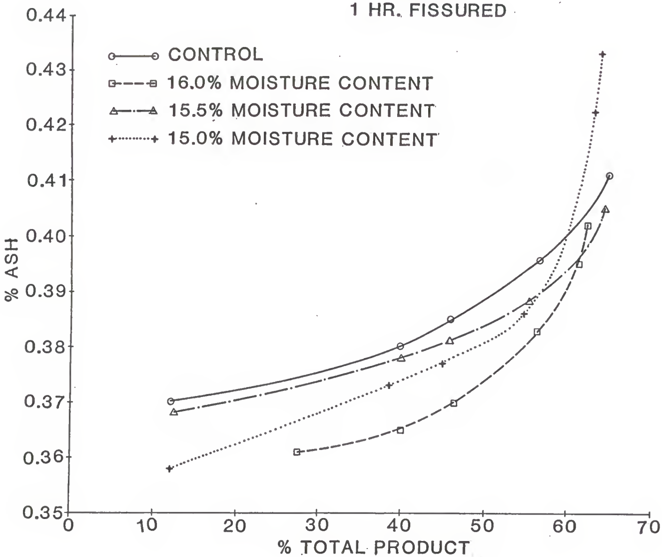


FIG. 4

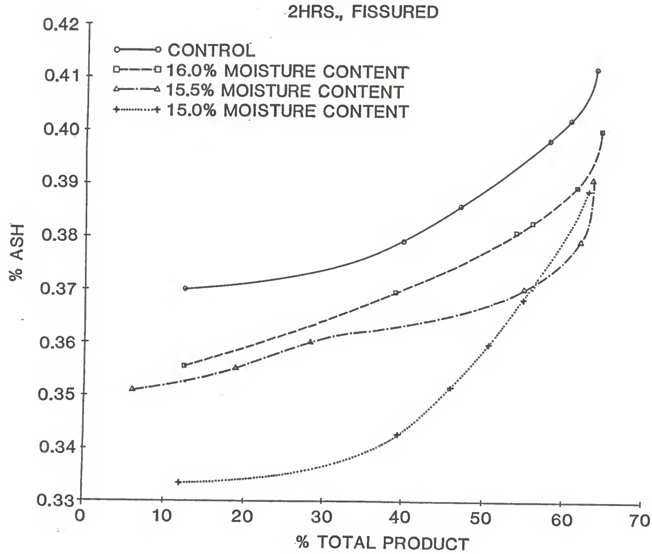

2HRS., FISSURED
CONTROL
16.0% MOISTURE CONTENT
15.5% MOISTURE CONTENT
15.0% MOISTURE CONTENT
% ASH
0.42
0.41
0.40
0.39
0.38
0.37
0.36
0.35
0.34
0.33
0
10
20
30
40
50
60
70
% TOTAL PRODUCT

FIG. 5

3HRS., FISSURED

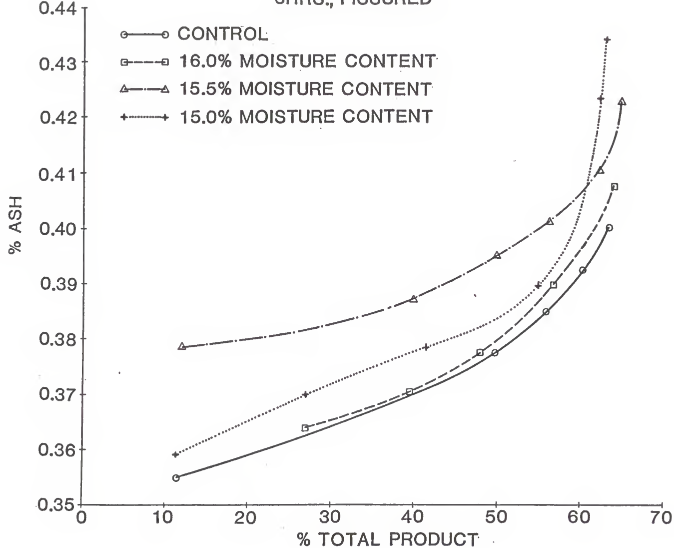


FIG. 6
4 HRS., FISSURED

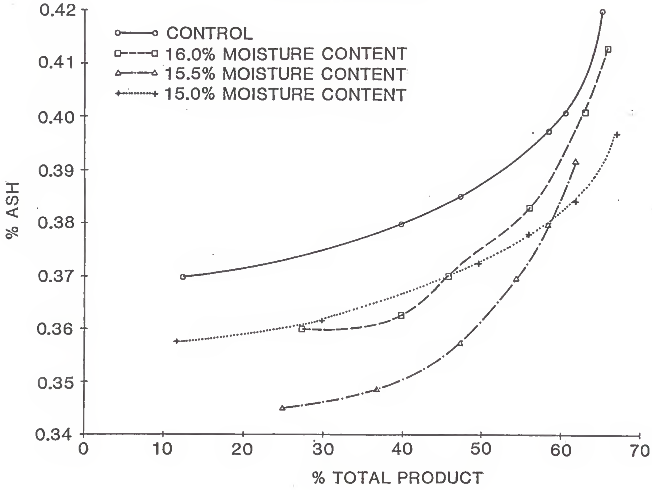


FIG. 7

5HRS., FISSURED

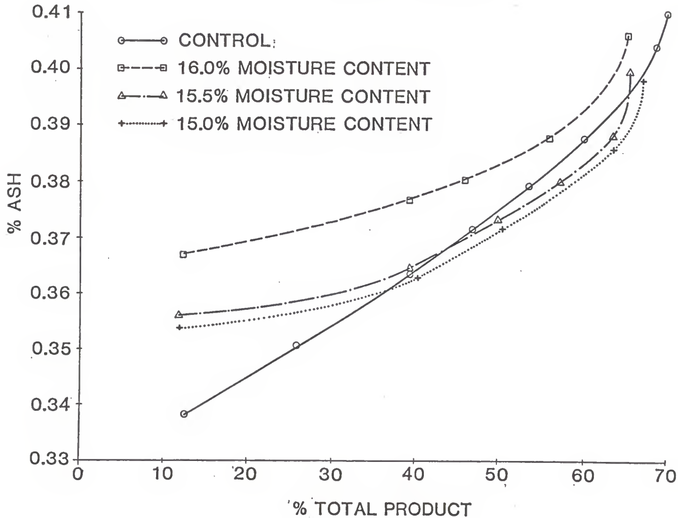


FIG. 8

6 HRS. FISSURED

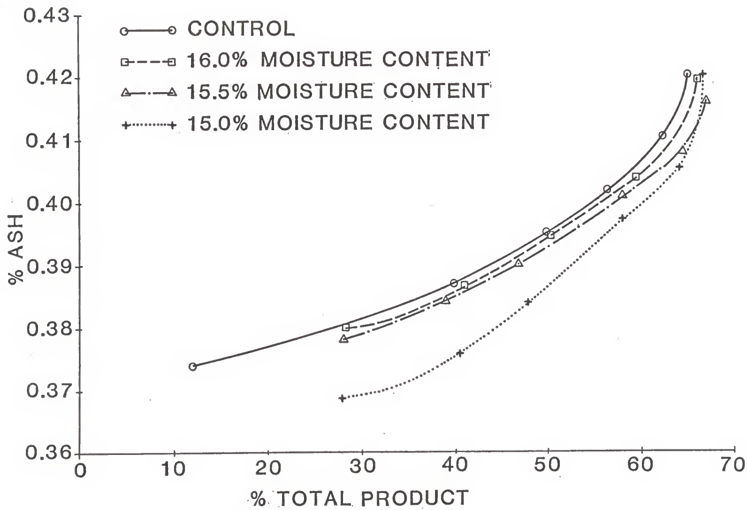
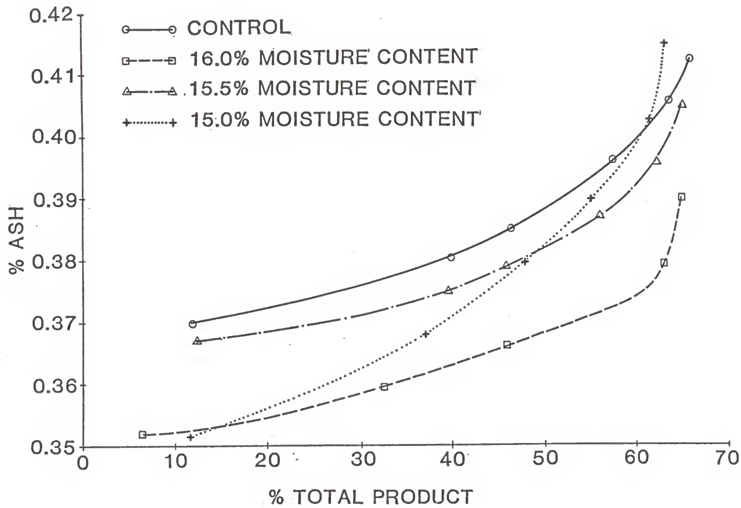


FIG. 9
7 HRS. FISSURED



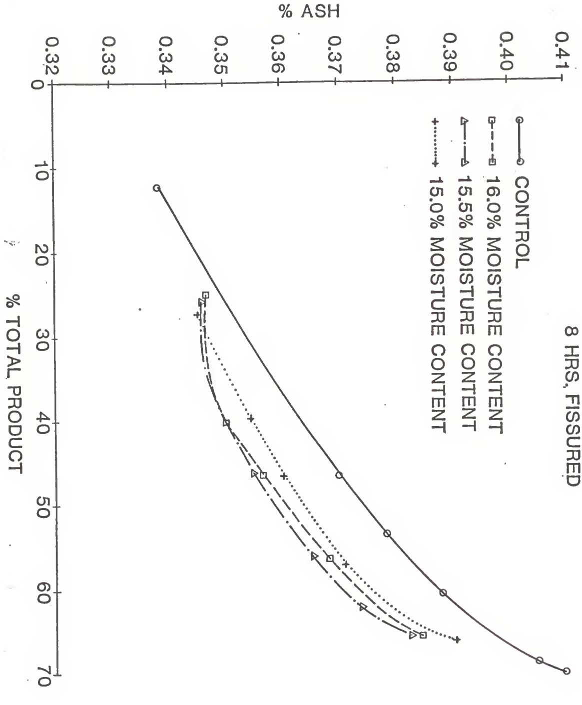
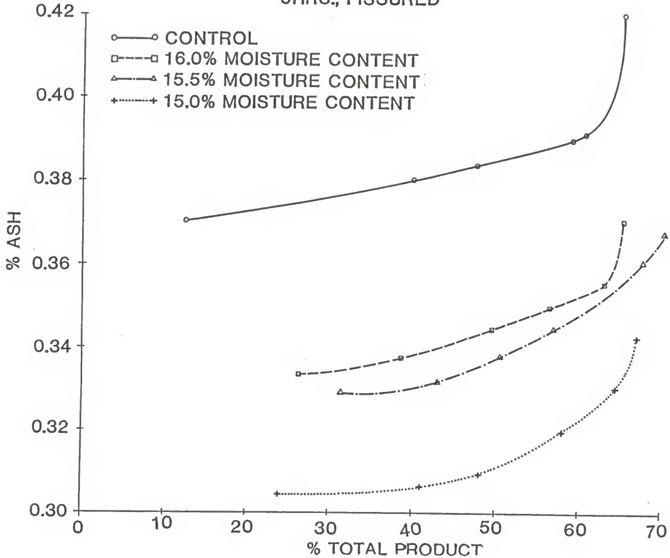


FIG. 10
8 HRS, FISSURED

FIG. 11

9HRS., FISSURED



14 indicate the surface response planes for extraction, ash and color and Figures 15 to 17 indicate the Agtron color scores for the control versus the experimental samples represented by bar graphs. As seen from the ash curves, bar graphs and the surface response planes it is very clear that there is a lowering of ash content by fissuring with an increase in color after a certain temper time in the case of the fissured samples as compared to the control samples. Results of the Fragment counts which were analyzed by the Acid Hydrolysis method has been indicated in table VII. As it can be seen from the table the fissured sample had the lowest fragment count when compared to the other two samples i.e.,the control sample and the pre-break integrated sample.

FIG. 12
FITTED RESPONSE PLANE FOR EXTRACTION

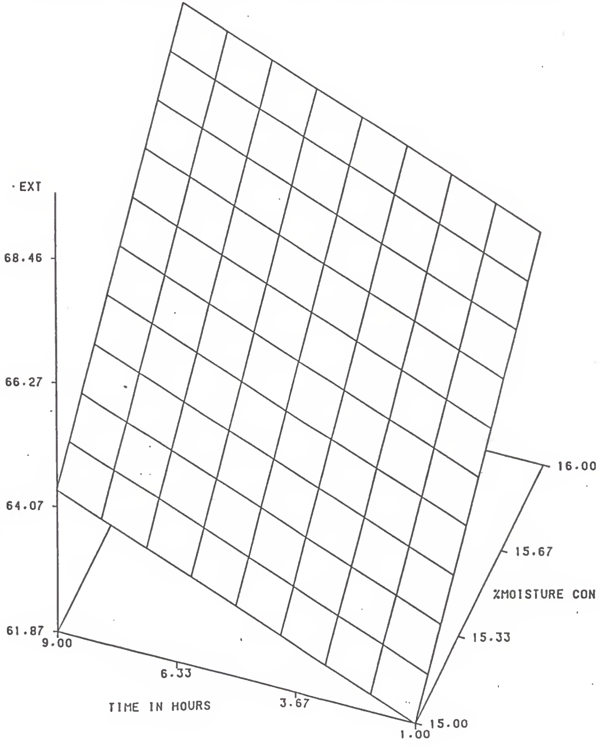


FIG. 13
FITTED RESPONSE PLANE FOR ASH

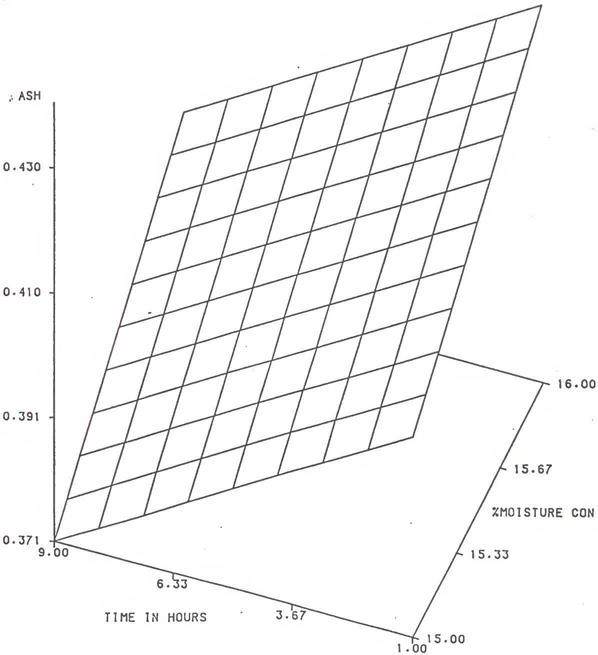


FIG. 14

FITTED RESPONSE PLANE FOR COLOR

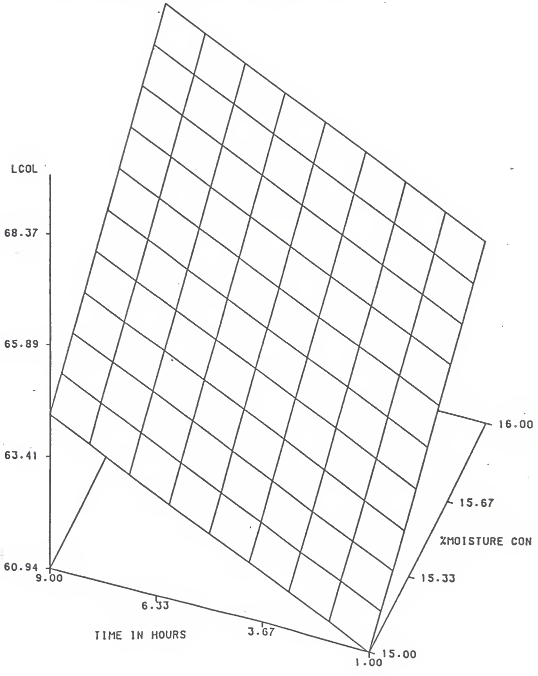


Fig. 15.

FLOUR COLOR

CONTROL VS. FISSURED @ 15%M.C.

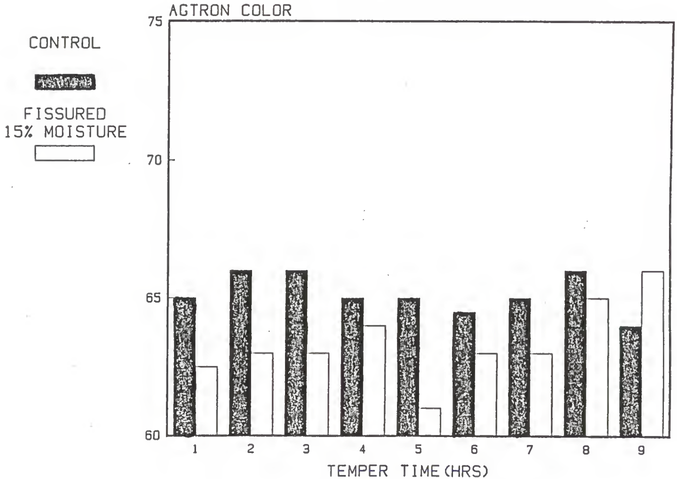
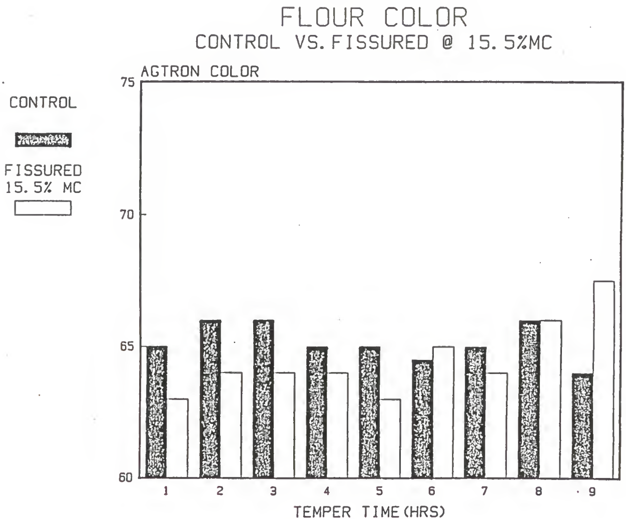


Fig. 16.



FLOUR COLOR
CONTROL VS. FISSURED @ 15. 5%MC
AGTRON COLOR
75
70
65
60
CONTROL
FISSURED
15. 5% MC
1
2
3
4
5
6
7
8
9
TEMPER TIME (HRS)

Fig. 17.

FLOUR COLOR

CONTROL VS. FISSURED @ 16.0%MC

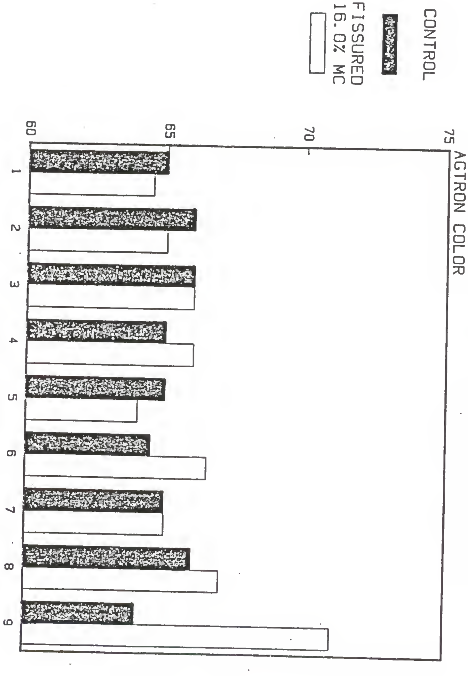


Table : VII Fragment Count as Determined by The Acid hydrolysis method.

Sample	Total Fragments
A	88.5
B	83
C	68

A- Control- (16% MC, 24 hrs, temper)

B- Pre- break- (16% MC, 24 hrs, temper)

C - Fissured - (16% MC, 9 hrs, temper)

CONCLUSION

As seen from this study, minimal fissuring of wheat before tempering hastens water penetration into the wheat kernel thus reducing tempering time without affecting extraction, color, and in the process lowering ash and fragment counts. If implemented commercially it could be a great boon to the miller for the benefits that he could accure such as a reduction in bin space for tempered wheat which accounts for a substantial sum of capital in any mill and with the additional benefit of lower ash and fragment counts and without a deterimental effect on flour quality.

Suggestions for future Work

Possibilities for future work may include the continuation of the same method on:

A> On different varieties of wheats such as Spring wheats, Hard Red Winter wheats, and soft wheats to establish roll gaps for fissuring determine the optimum conditioning time for each of the above mentioned varieties, and evaluate the milling properties of each of them.

B> To study the possibility of commercially implementing the method by putting up a Roller Mill in the cleaning house of the K.S.U. pilot mill which would be used for the fissuring operation.

C> To carry out energy studies on the proposed dry wheat fissuring prior to tempering method when compared to pre-break integrated mills.

D> To determine as to wether fissuring loosens up the bonds between the bran and the endosperm by scanning electron microscopy.

E> To study the behaviour of water absorption in fissured and tempered wheat kernels using Differential Thermal Analysis (D.T.A).

F> To determine fat levels in fissured wheat flour samples and control flour samples.

G> To determine the % age and quality characterstics of the material removed by aspiration after fissuring as compared to the pre-break integrated samples.

H> To evaluate fragment counts in flour using the Entoletor Scourer Aspirator as compared to the conventional pre-break and proposed fissuring method.

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SECTION B: EVALUATING FLOW PROPERTIES OF DRY, TEMPERED, AND FISSURED YECORA ROJO WHEAT.

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INTRODUCTION

Early designers of bins for the storage of bulk solids assumed that stored materials behaved like liquids and, thus , designed the vessels for equivalent fluid pressures (1).The first generation of bin research was well summarized by Ketchum (2) in 1909. Experiments by Roberts (3) on models and full size bins showed that this is incorrect i.e., solid materials did not behave like liquids for equivalent fluid pressures, that some of the weight of the grain is transferred to the bin walls by friction. Jannsen (4) confirmed this conclusion and derived formulas and published a theory that accounted for wall friction. His formulas were widely used in Germany. Airy (5) also derived a set of formulas and tested the angle of repose and frictional properties of grains and bin wall materials. Prante (6) concluded that bin pressures were not constant but varied according to the condition of flow.

A second generation of bin research was developed by the 1930's , when many methods of construction had been changed and safety factors were altered. Much of this research took place in Russia and France (6). Tests were conducted in Russia in 1939 to determine the cause of cracks in bins designed according to Jannsen's theory. Lateral pressures were found to be two to three times greater than those provided for in Jannsen's formula. The Russians concluded that the conditions and pressures were higher

when the grain bins were being emptied (7).

Other researchers (8) measured pressures at the bottom of bins while the Russians measured the pressures along the entire bin height. They determined that maximum lateral pressures usually do not occur at the lowest point of the bin.

Some work was also performed in an effort to cause bins to flow in a last in first out manner and thus, to reduce stress on the bin walls. Mass flow creates higher stresses than non-mass flow under certain conditions. In general the second generation of research provided us with the knowledge that grain bin flow technology could be improved , both from a usage and structural standpoint.

The third generation of bin research provided an understanding of why grain flows as it does within a bin. Jenike and Johanson (9) have done extensive work on this. They have been able to predict the pressures and flow characterstics within flowing bins.

It may be useful to the reader to learn certain commonly used terms and their definitions in order to understand the flow properties of materials.We all know that bulk solids such as grain, flour, feed etc are assemblies of discrete solid particles. The properties of solids refer to the assembly of their particles. Some of the important parameters that we are concerned about in bulk solids are as follows:

1>Bulk Density:Bulk density ,also known as γ is the weight of a bulk material per unit volume. The easiest way to measure bulk density is to weigh the whole cell after it has been sheared to failure, subtract the weight of the cell itself, and divide the net weight by the volume of the cell.

2>Particle Size: Granular materials are generally non-cohesive and free flowing, but our interest lies in the conditions that lead to stoppages of flow. Stoppages occur when the solid reaches an excessive yield strength. Thus, the critical conditions to be considered are those of highest strength. During the flow of a mass of mixed particle sizes, the larger particles move bodily while the material shears across the fines. Therefore, the yield strength of the mass depends upon the properties of fines. Coarse particles are passive agents and, like aggregates in concrete, do not develop yield strength without fines to bind them.

3> Flow Function (FF): Flow function is the relationship between the cohesive strength of the material and consolidation pressure. A material's flow function is measured on a shear tester or similar instrument. The test procedure involves applying compressive loads to a sample of the bulk solid and then shearing the solid to determine its strength. The minimum discharge outlet dimension that is required to ensure reliable flow is calculated from these results. A material's cohesive strength is primarily

affected by moisture content, particle size distribution and storage time. Cohesive strength will typically increase as the material's moisture content increases, its particle size decreases, or its storage time lengthens (11).

4>Flow Factor (ff): During flow of materials from bins there are infinite number of obstructions to flow. Observations indicate that a solid will flow if a dome does not develop across the channel. For an obstruction to occur in a channel, the solid has to be consolidated to such a degree that it develops sufficient strength to support the weight of the obstruction. Hence , the higher the consolidating pressures, i.e., major consolidating pressure in a channel, and the lower the major pressure in a dome or a pipe, which acts in an obstruction, the lower the flowability of the channel. This is expressed by the flow factor. Flow factor charts for arching in mass flow in conical channels and plane flow channels have been prepared by Jenike (9).

With a brief background on some of the properties of solids it would be interesting to briefly discuss the flow patterns that occur in bins. There are three types of flow patterns namely, mass flow, funnel flow and expanded flow.

A>Mass-Flow: With mass flow ,the hopper is sufficiently steep and smooth to cause flow of all the solids in the bin without stagnant regions during discharge. In mass flow bins, the flow is uniform, and the bulk density

of the feed is practically independent of the head of the solids in the bin. This frequently permits the use of volumetric feeders for feed rate control. Low level indicators work reliably. In addition, segregation is minimized because, while a solid may segregate at the point of charge into the bin, the first-in, first-out flow sequence enforces the same particle size distribution to exit the hopper as was put into it. This flow sequence also ensures uniform residence time and de-aeration of fine powders.

Generally, mass-flow in bins provides a smooth withdrawal movement of the materials. Occasionally, however, when the design is marginal, a jerky movement may develop, caused by partial arching or a slip-stick movement among the walls. This jerky movement may set up severe vibration problems in the structure. Mass flow bins are generally recommended for cohesive materials, materials that degrade with time, and powders, or when segregation needs to be minimized.(12)

B><u>Funnel Flow</u>: Funnel flow occurs when the hopper is not sufficiently steep and smooth to force material to slide along the walls or when the outlet of a bin is not fully effective, due to poor feeder or gate design. In a funnel-flow bin, the bulk solids flow toward the outlet through a vertical channel that forms within stagnant material. The diameter of that channel approximates the

largest dimension of the effective outlet. When the outlet is fully effective, this dimension is the diameter of a circular outlet, or the diagonal of a square or slotted outlet. Powders withdrawn at a high flow rate from a funnel-flow bin may remain fluidized because of the short residence time in the flow channel and flush during withdrawal from the bin, making control of the product discharge rate quite difficult.

As the level of the bulk solids within the channel drop, layers slough off the top of the stagnant mass into the channel. This flow behaviour is detrimental with cohesive solids, since the falling material packs, thereby increasing the chance of arching. A channel, especially a small, high velocity channel, may empty out completely (rathole),and powder charged into the bin then flushes through.

Since funnel flow bins are more likely to cause arching of cohesive solids than mass-flow bins, they usually require larger outlets for dependable flow. These bins also cause segregation of solids and are unsuitable for solids that degrade with time in the stagnant regions. Cleanout of a funnel-flow bin is often uncertain, because solid in the stagnant regions may cake and pack. Funnel flow bins are only suitable for coarse, free-flowing or slightly cohesive, non-degrading solids when segregation is unimportant (12) .

C><u>Expanded Flow</u>: This is a combination of mass-flow

and funnel-flow.The lower portion of the hopper operates in mass-flow. The mass flow outlet usually requires a smaller feeder than would be the case for funnel flow. The mass-flow hopper should expand the flow channel to a diagonal or diameter equal to or greater than the critical rathole diameter, thus eliminating the likelihood of ratholing.

These bins are recommended for the storage of large quantities of non-degrading solids. This design is also useful as a modification of exsisting funnel-flow bins to correct erratic flow caused by arching, ratholing or flushing. This concept also can be used with multiple outlets where simultaneously flowing, mass-flow hoppers are placed close enough together to cause a combined flow channel in excess of the critical rathole diameter.

Normally these three flow patterns are axi-symmetrical in relation to the bin or silo walls, since the outlet is located in the center line of the bin. This symmetry has many advantages in terms of flow and structual design. For reasons of layout, capital cost, or the designers past practices, many non-symmetrical bins and hoppers are built, or sometimes symmetrical bins with off-set outlets. Because of this non-symmetrical bin or hopper configuration, eccentric withdrawal from multiple outlets or side outlets, and eccentric loading spouts, the resulting flow patterns can develop severe problems in storage facilities.

Quite often, eccentric withdrawal patterns can also be developed in symmetrical bins, when the feeder is not properly designed or selected, or when the cut-off gate is left partially closed. The off-center vertical flow patterns caused by feeders or gates will have the same structural effects on the bin as those in a non-symmetrical bin (12).

OBJECTIVES

The main objective of this study was to determine the flow characterstics of dry, tempered, and fissured-tempered Yecora Rojo Wheat grown in the state of California, with the aid of the Jenike's flow factor tester.

MATERIALS AND METHODS.

The main objective of this work was to compare the flow properties of dry, tempered and fissured -tempered wheat kernels in conditions simulating the flow inside a bin or hopper.This flow is characterized by a continual shearing deformation under pressure. A direct shear test was used to measure the flow properties. This procedure was essentially followed in running the tests used for the measurement of the flow factor in this report. A 3.5 inch inside dia shear cell was used in the tests. The cell was positioned on the flow function machine and filled with the wheat to be tested which was dry whole wheat kernels, tempered whole wheat kernels, and fissured wheat kernels. All the samples of wheat were " Yecora Rojo " grown in the state of California.Throughout the course of the tests the moisture content of the dry wheat, tempered wheat and fissured wheat were kept constant. The dry wheat had an initial moisture content of 11.8%, and the final moisture content of the fissured and tempered wheat were kept constant at 16.0% . All moisture measurements were made with a Dicky John Motomco Grain Moisture Tester, Model 919.

Consolidation of the sample was carried out in two stages. The first stage is known as pre-consolidation and its purpose is to prepare a uniform specimen. With the cover of the test cell, a packing mold was placed on top of the ring, and both the mold and the ring were placed in an

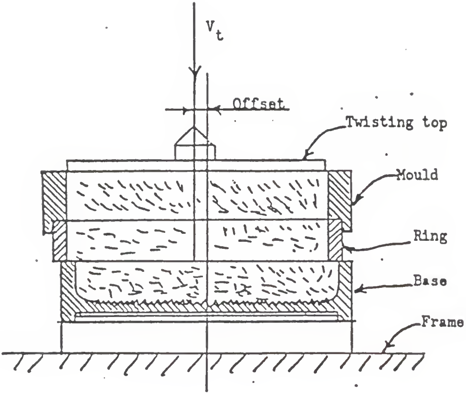
offset position on the base, as shown in Figure 1. A sample of the material to be tested was then placed in the shear cell and one layer after another was slightly packed with the fingers to fill the mold. The excess material was scraped off level with the top of the mold. A twisting top was placed over the solid and a vertical force Vt was applied to the top by means of weights, Vt causes a vertical pressure sigma t (σ_t) in the material. By means of a special wrench, about 20 oscillating twists were applied to the cover. The twisting top , mold, and the vertical load Vt were then removed, and the excess material was scrapped off level with the top of the ring. Consolidation was completed by placing the shear cell containing the sample of wheat on the consolidation bench, Figure 1A , and covered with plastic covers which seals it against moisture loss. The sample was then left on the consolidating bench for 24 hrs for dry and tempered wheat and 12 hrs for fissured-tempered wheat (10). This represented the time that the material is in the bin without flow. After this period the sample is sheared to failure.

The Jenike flow factor machine which consisted of a shear unit with a shear cell frame, a vertical load applicator, and an instrument cabinet was used for the tests as seen in Figure 1B.

The procedure for the shear test was as follows:

The electrical connections were switched on and a chart was

FIG. 1



Preconsolidation of a shear cell

FIG. 1A CONSOLIDATING BENCH

FIG. 1B JENIKES FLOW FACTOR TESTER

placed on the recorder. The recorder pen was placed on the blue pen holder, and air supply was turned on and the air pressure was adjusted to 70 psig. The weights for pre-consolidation, consolidation, and the shear tests were determined as follows:

Three sets of weights on weight hangers were prepared. The pre-consolidation weight (Vt) and the shear weight ($\overline{V}$) were calculated from the desired consolidation weight (V) using the following equations : Vt=1.86 V and $\overline{V}$= 2/3 V. Vt, V and $\overline{V}$ are always denoted in lbs. The amount of weight to be used on each hanger for pre-consolidation, consolidation, and the shear test was then calculated from the following equations :

$$\text{(a)} \quad Wh\,(Vt) = \frac{Vt - 3.716}{MF} - 0.2$$

$$\text{(b)} \quad Wh\,(V) = \frac{V - 3.716}{MF} - 0.2$$

$$\text{(c)} \quad Wh\,(\overline{V}) = \frac{\overline{V} - 3.716}{MF} - 0.2$$

where MF= Multiplication factor and Wh= hanger weight.

The multiplication factor used was determined by the hole used on the weight application bar. If the first hole was used, the MF was 2, if the second hole was used the MF was 3, and if the third hole was used the MF was 4. e.g. If the desired consolidation weight was 20lbs, Pre-Consolidation weight Vt = 1.86(V) i.e. Vt = 1.86* 20 = 37.20 lbs, and the

shear weight $\overline{V} = 2/3(V)$ i.e. $\overline{V} = 0.66 * 20 = 13.33$ lbs. Once these weights were calculated , they were substituted in equations a, b, and c, to determine the respective weights to be used on each hole of the weight hanger for the pre-consolidation, consolidation and shear tests respectively during the tests. For example if the 1st hole was used , from equation (a) we have to find the pre-consolidation weight :

$$Wh\ (Vt) = \frac{37.20 - 3.716}{2} - 0.2 = 16.5 \quad \text{lbs}$$

Equation (b) gives us the weight to be used for consolidation on the consolidating bench as well as the consolidation test. From equation (b) the consolidation weight (V) is :

$$(V) = \frac{20 - 3.716}{2} - 0.2 = 7.9 \text{ lbs}$$

From equation (c) the shear weight $(\overline{V})$ is :

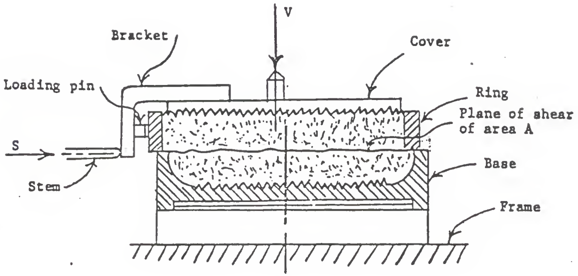
$$(\overline{V}) = \frac{13.33 - 3.716}{2} - 0.2 = 4.6 \text{ lbs}$$

In the same way, weights were calculated for the other holes. Washer weights were used for small increments of weight. Each washer weight was approximately one tenth of a pound. Once the pre- consolidation was carried out and the sample was consolidated for the required time, the sample

then was used to carry out the consolidation and the shear tests.The shear cell containing the sample was gently removed and then set up against the guide screws of the test machine. The consolidation weight then was applied to the weight frame by placing the weight hanger in the appropriate hole. The plunger then was advanced with the hand wheel until it touched the loading pin and then the flow factor tester was turned on, as seen in Figure 2. The sample was sheared until the ring of the shear cell was centered on the base. The flow factor tester was turned off, and the plunger was retracted. The consolidation weight was removed,and the shear weight was then applied,the plunger was re-advanced and the flow factor tester was turned on. The sample was then sheared until the curve printed by the recorder peaked. The flow factor tester was then shut off, and the shear weight was removed. The peaks of the two curves printed by the recorder were then marked as S and $\bar{S}$. A typical recorder chart is shown in Figure 3, with the curves numbered as 1 (consolidation test) and 2 (shear test). This test was repeated for all the samples on all the three holes, giving a total of 54 tests on the Yecora Rojo wheat.

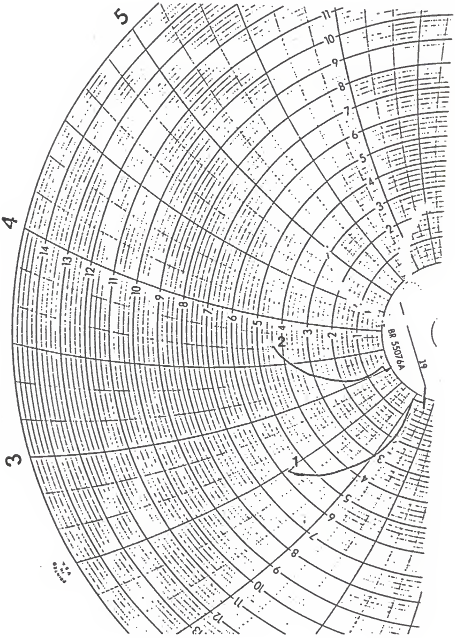
For the consolidation and the shear tests essentially three sets of weights were used i.e., 20 lbs, 25 lbs, and 30 lbs. For each set of weights, the test was conducted at all three holes. Once the tests were completed, S and $\bar{S}$ values were noted from the recorder graph and the values of K, V1,

FIG. 2



A shear cell

FIG. 3



and F were determined using the following relationships.

$$a)\ K = \frac{S - \bar{S}}{V - \bar{V}} + \sqrt{1 + \left(\frac{S - \bar{S}}{V - \bar{V}}\right)^2}$$

$$b)\ V1 = V + KS$$

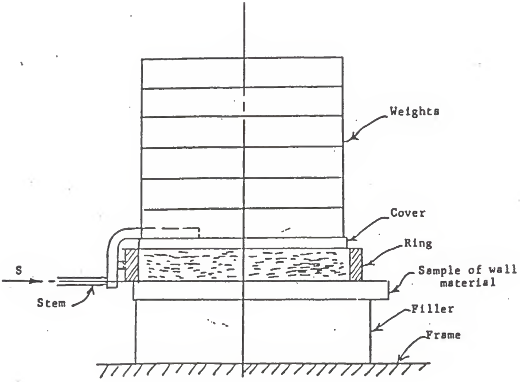
$$c)\ F = 2K\left[S - V\left(\frac{S - \bar{S}}{V - \bar{V}}\right)\right]$$

where S and $\bar{S}$ are the peaks of the consolidation tests and the shear tests as recorded by the recorder. V and $\bar{V}$ are the consolidation weights, and the shear weights, respectively where K= coefficient , V1 = the major consolidating force in lbs, and F = unconfined yield force in lbs.

The kinematic angle of friction test, which measures the angle of friction between a solid and the wall material (brass) can be performed on the same machine. The recorder pen was placed on the red pen holder for the test.

The Jenike theory (9) states that a set of weights totalling 7 lbs are determined as appropriate i.e. two sets of 2 lb weights and three sets of 1 lbs weights. The set of weights were placed directly above the sample as seen in Figure 4. The plunger was advanced with the hand wheel until it touched the loading pin, and the flow factor tester was turned on. The material was sheared until the ring of the shear cell was centered on the base. The 2 lb weight on top was removed, then when the curve printed by the recorder

FIG. 4

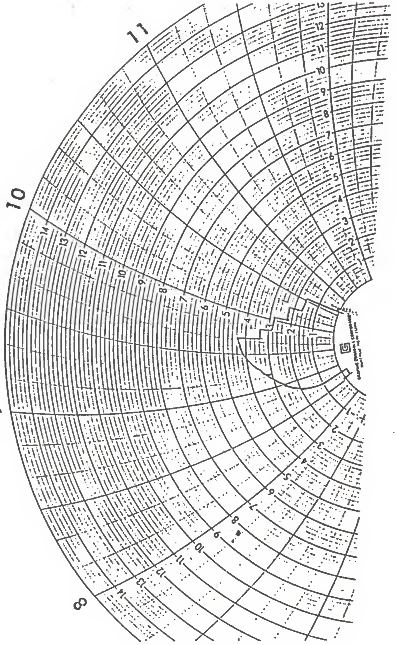


Measurement of the kinematic angle of friction between a solid and a wall material

peaked, a 1 lb weight was removed. Each time the curve peaked another 1 lb weight was removed until all the weights had been removed. The peak value of each step was recorded as S1 through S7. A typical recorder chart for the kinematic angle of friction test is shown in Figure 5.

The bulk density of the material was also determined using the following method . Shear cell samples of dry, tempered, and fissured wheat were prepared and weighed after they were sheared to failure. This weight was subtracted from the weight of the empty cells and divided by the net volume of the cell.

FIG. 5



RESULTS AND DISCUSSIONS

The results of the consolidation and shear tests are given in Table I. The F values were small for dry wheat but increased for tempered wheat and more for fissured wheat. In order to determine the flow functions, we plotted the test results of V1 vs F, i.e. V1 on the absicca and F on the ordinate, where V1 is the major consolidating force in lbs and F is the unconfined yield force in lbs, and thus we drew the flow function curves for dry, tempered, and fissured wheat as seen in Figure (6). There was a distinct difference between dry, tempered and fissured wheats. The highest curve,i.e that for fissured wheat marks a solid with the most strength, and the greatest ability to support obstructions to flow, and hence, the least free flowing. On the other hand, dry wheat developed very low, unconfined, yield strength and was very free flowing . Tempered wheat developed a more unconfined yield strength as compared to dry wheat but would still flow more easily than fissured wheat. The slope of each flow function curve was determined and the flow functions of the three wheats were then obtained by dividing V1/F. The results are reported in Table II.

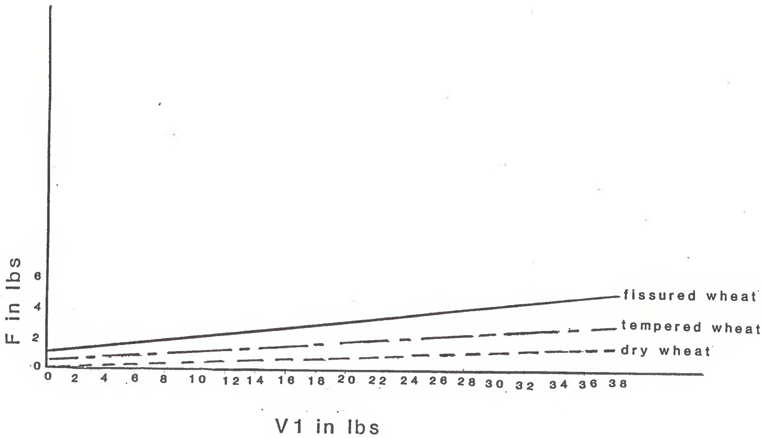
The flowability of solids have been classified by Jenike according to the limiting FF- values : less than 2, is very cohesive and non-flowing, between 2 and less than 4 the material is said to be cohesive, between 4 and less than 10

Table : I Percent Total Flour Extraction

Temper Time in hrs	Control (24 hrs)	Fissured Samples 15.0% m.c	15.5% m.c.	16.0% m.c
1	65.6	63.9	64.8	65.0
2	65.5	64.1	64.3	64.6
3	64.5	63.9	64.9	63.8
4	65.0	62.3	64.6	65.0
5	70.4	66.3	65.9	64.8
6	64.9	66.3	66.5	66.8
7	65.5	65.2	64.8	65.2
8	69.9	65.9	65.1	65.5
9	64.9	65.0	66.9	69.9

m.c. denotes moisture content

FIG. 6 Flow function curves for dry, tempered, & fissured wheat



the material is said to be easy flowing, and 10 and above is said to be free flowing. Dry and tempered Yecora Rojo wheat fall under the category of free flowing, since their flow functions were 20 and 18 respectively but fissured wheat falls under the category of easy flowing since it has a flow function of 5.85 i.e. 6. One of the principal reasons for the lower flow function of the fissured wheat was the presence of a certain amount of fines, which acted as a binding agent and help the material to pack when moisture was added to it during tempering. Whereas in the case of dry and tempered wheat coarse particles acted as passive agents during flow. The bulk density of dry ,tempered and fisssured wheat was also determined and the results of which have been indicated in table II.

Results of the kinematic angle of friction test are indicated in Table II. To determine the value of ϕ' plots of V vs S were made as seen from Figures (7),(8), and (9) for dry, tempered, and fissured wheat respectively and a smooth line was drawn through these points and this was known as the wall yield locus. The value of ϕ' was then determined from the slope of the line and the Tan inverse of that value gave the value of ϕ'. There was a clear distinction in the values of ϕ' i.e 27 deg. for dry wheat 42 deg. for tempered wheat, and 45 deg. for fissured wheat. The kinematic angle of friction indicated the bin walls resistance to the material sliding along it's surface. The

Table:II Limiting Flow Function values, Bulk Density, and kinematic angle of friction for dry, tempered and fissured Yecora Rojo Wheat.

Wheat	FF	Class	Bulk-Density	ϕ' in deg
Dry	20	free-flowing	45	27.5
Tempered	18	free-flowing	40	42
Fissured	6	easy-flowing	39	45

where FF denotes Flow Function

Bulk density is in lbs/cu ft

ϕ' is the kinematic angle of friction between the solid and the wall material in degrees.

FIG. 7 Kinematic Angle of Friction for Dry Wheat

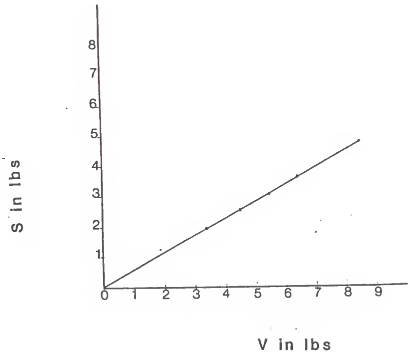


FIG. 8 Kinematic Angle of Friction for Tempered Wheat

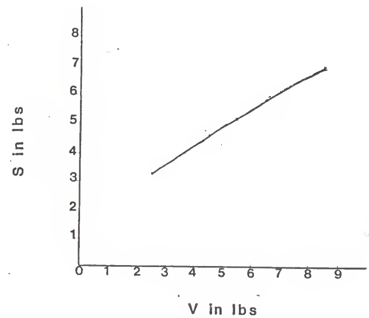
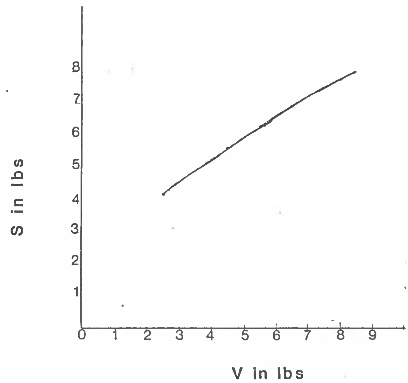


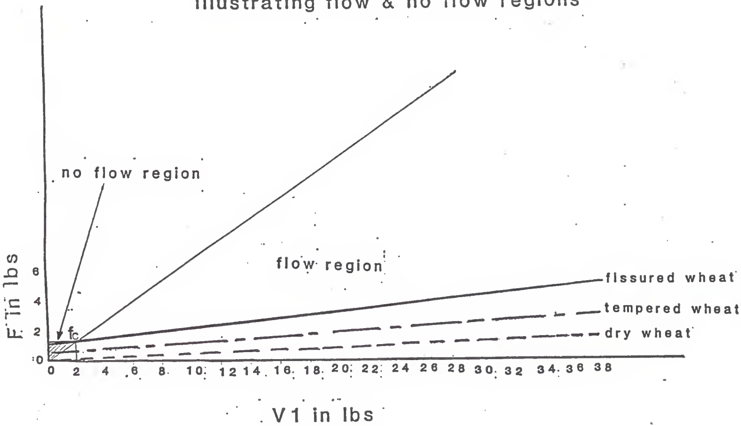
FIG. 9 Kinematic Angle of Friction for Fissured Wheat



results clearly show that there was more friction in the case of fissured wheat followed by tempered wheat with the least amount of friction in the case of dry wheat.

The next step was to determine the hopper outlet, that was required for the material to flow without arching. In order to determine diameter of the outlet we plotted flow function curves (Figure 10) for dry, tempered and fissured wheat, with the objective of determining the value of fc (the crtical value of the material strength). With ff known,i.e 2 in this case (9), the critical value of fc was determined by drawing the flow factor line on the flow function line (FF plot) . To the right of the intersection of ff with FF, fc is less than V1, and an arch cannot be supported whereas to the left, the opposite is true. The two regions are known as the flow and no- flow regions, respectively , and the no flow region for fissured and tempered wheat has been hatched in Figure (10). The intersection itself gives the critical value of fc, which was 1.3 for fissured wheat and 0.6 for tempered wheat. In the case of dry wheat, fc could not be determined because the ff line did not intersect with the FF line. This implies that there is no cohesion in the case of dry wheat so it is very free flowing. It is important to remember difference between flow factor and flow function. Flow Function is a measured property obtained from testing, whereas the flow factor is a calculated value representing the stress field

FIG. 10 Flow function curves for dry, tempered, & fissured wheat illustrating flow & no flow regions



condition in an arch and has been published by Jenike (9). Jenike and Johanson (13) suggest the following diameter dimensions for circular outlets: $d \geqslant \dfrac{2.2\ fc}{\gamma}$

where fc is the critical value of the material strength which was 1.3 for fissured wheat and 0.6 for tempered wheat as seen from Figure (10).

γ is the bulk density which was 39 lbs / cubic foot for fissured wheat and 40 lbs / cubic foot for tempered wheat.

The flow factor used for calculating the hopper outlet was 2, i.e. ff= 2.

Sample Calculations:

1> Fissured Wheat, ff = 2,

$$A = \frac{3.142\ (3.75 * 3.75)}{4} = 11.05 \text{ in}$$

where A= area of the shear cell, and d= diameter of the shear cell = 3.75 in.

$$d = \frac{2.2 * fc * 12 * 12}{A * \gamma}$$

$$d = \frac{2.2 * 1.3 * 12 * 12}{11.05 * 39} = 0.96 \text{ ft}$$

In order to ensure flow for fissured wheat the minimum diameter for the hopper outlet should be at least 1 ft.

2> Tempered Wheat: ff = 2.

$$d = \frac{2.2 * 0.6 * 144}{11.05 * 40} = 0.43 \text{ ft}$$

In order to ensure flow for tempered wheat the minimum diameter for the hopper outlet should atleast be 0.45 ft. Since dry wheat is very free flowing, the hopper outlet diameters used for either tempered or fissured-tempered wheat would be acceptable.

CONCLUSION

Based on the flow function values resulting from the tests, it is clear that the flow characteristics of fissured wheat vary from those of tempered and dry wheat. The bin designer has to take into account the change in bulk density, the kinematic angle of friction, and flow properties to design bins and hopper outlets that would prevent funneling. Thus, a knowledge of these parameters would help in the better design of bins. As seen from this study, bins designed for fissured wheat would be acceptable for dry and tempered wheat. A larger hopper diameter is necessary for fissured wheat but dry and tempered wheat have higher flow functions, and lower values of fc i.e., critical values of material strength .

Suggestions for future Work

Possibilities for future work may include the continuation of the same method on:

A> Fissured, Tempered and Dry wheat and use the Mohr's circle theory to analyse the data.

B> To conduct the tests on different varieties of wheat such as Spring Wheats, Hard Red Winter Wheats, and Soft Wheats.

C> To build model bins made out of flexiglass based on test results of the Jenike Flow Factor Machine to verify the experimental results of the Flow Factor Tests.

D> To conduct shear and consolidation tests on intermediate stocks in the mill as well as finished products such as shorts, red dog, and flour.

E> Conduct the kinematic angle of friction test on other materials such as steel, concrete and others which are used in the construction of bins.

F) To conduct the flow function and the kinematic angle of friction test on different kernel sizes.

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REDUCTION OF TEMPERING TIME IN MILLING BY MINIMAL FISSURING OF WHEAT

by

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Wheat conditioning is one of the most complex aspects of milling and it could be defined as the treatment of wheat by a combination of moisture, time and in some cases heat. The purpose of conditioning is to toughen the bran and mellow the endosperm, so that it fractures easily and the bran would not splitter to a great extent during the milling operation. The objective of this research was to study the effect of fissuring wheat kernels prior to the conditioning process. The Buhler Experimental Mill was used for milling the samples. A Hard Red Winter Wheat i.e. Arkan variety grown in the State of Kansas was used for all the experiments.

The testing involved milling wheat as whole wheat kernels as done in commercial milling and this was known as the control samples, and also fissuring wheat which was given a 0. 5% pre-temper and then fissured using a pair of smooth rolls operating at a differential of 1:1 and then tempering them to the desired final moisture content before finally milling them. These were known as the experimental samples. Flours from each milling were weighed and analyzed for both moisture, ash content and color. Cumulative flour ash was then calculated for each milling. To analyze the effect of fissuring on milling quality, for each test, cumulative flour ash was plotted against the cumulative percentage of total products, for the control samples as well as the

fissured samples.

Fragment counts were also carried out to determine wether fissuring had any effect on the samples.

The analysis of the test results indicated that ash could be significantly lowered and flours with higher color scores,& lower fragment counts could be obtained in the case of the fissured samples when compared to the control samples. Extraction rates of fissured samples were comparable to that of the control samples .

The flow properties of fissured wheat, dry wheat and tempered wheat were determined using the Jenike Flow Factor Machine. The analysis of the test results showed that that dry wheat as well as tempered wheat were free flowing whereas fissured wheat was not.